CS 598 WSI, LECTURE2

Q.1. How do two wireless devices communicate?

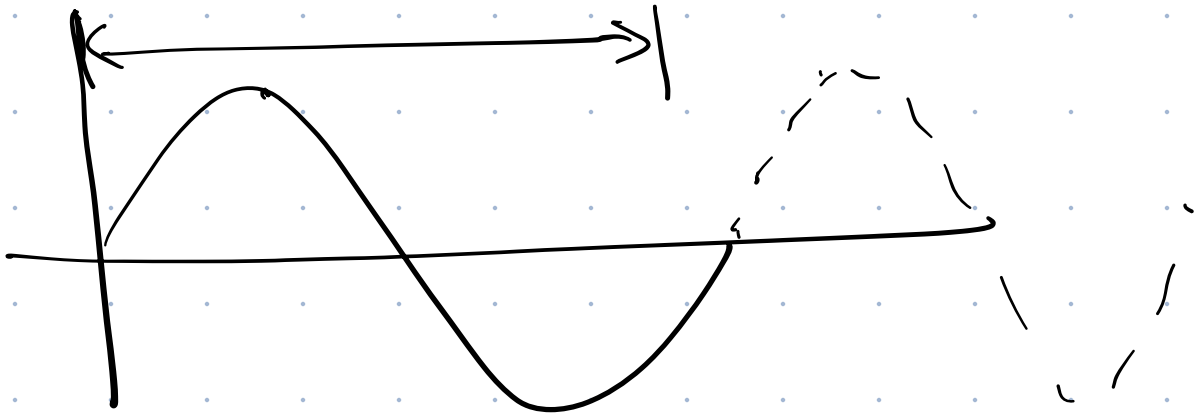
Q.2. Why do I experience bad service sometimes?

Part 3: Zigzag basics

Reminders

- Reading assignments
- Scribe notes.
- Ed

WIRELESS SIGNALS AS WAVES



wavelength (λ) → space/distance (m/cm)

frequency (f) → time (Hz → /s)

$c = \lambda f$ ← wavelength, ← freq.

c = speed of light

3×10^8 m/s

Wi-Fi (unlicensed) ≈ 2.4GHz $= 2.4 \times 10^9$ Hz

wavelength ≈ 12cm.

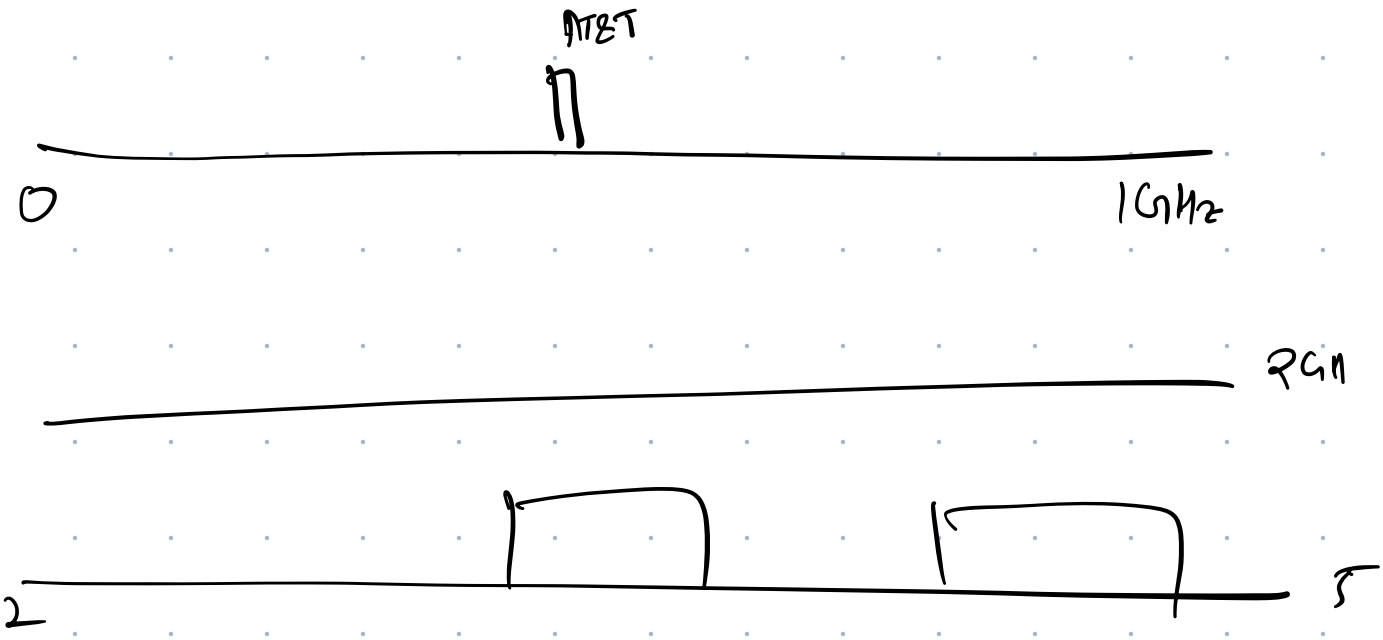
→ { 5GHz $\approx 5 \times 10^9$ Hz
wavelength ≈ 6 cm }

↳ harder to travel through obstacles

Cellular ≈ (licensed)
- 700 MHz → $\lambda \approx$ 40 cm
- 1800 MHz / 1.8 GHz → $\lambda \approx$ 16 cm
- newer → 3500 MHz

Spectrum ≈ frequencies

unlicensed Cellular → basestation that I can (CBRS) transmit at.



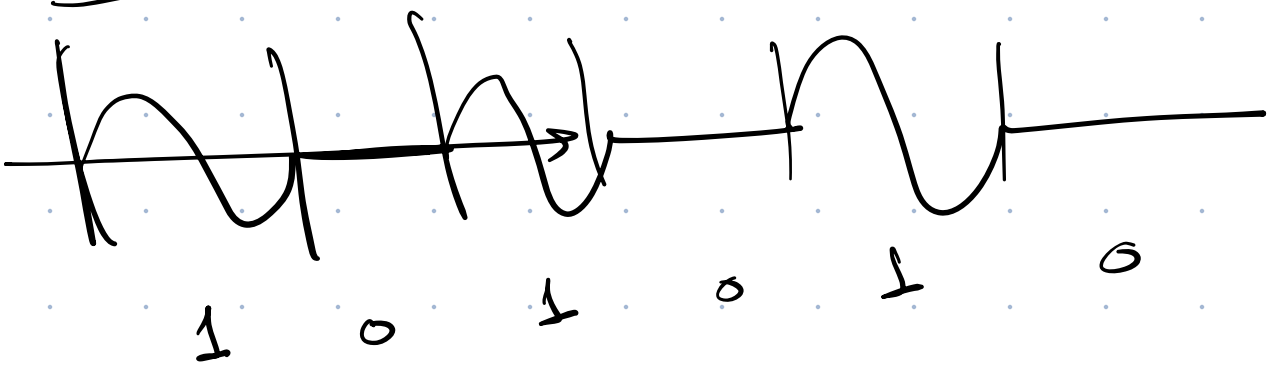
o.k

BRAINSTORM: WHAT CAN WE DO WITH WAVES?

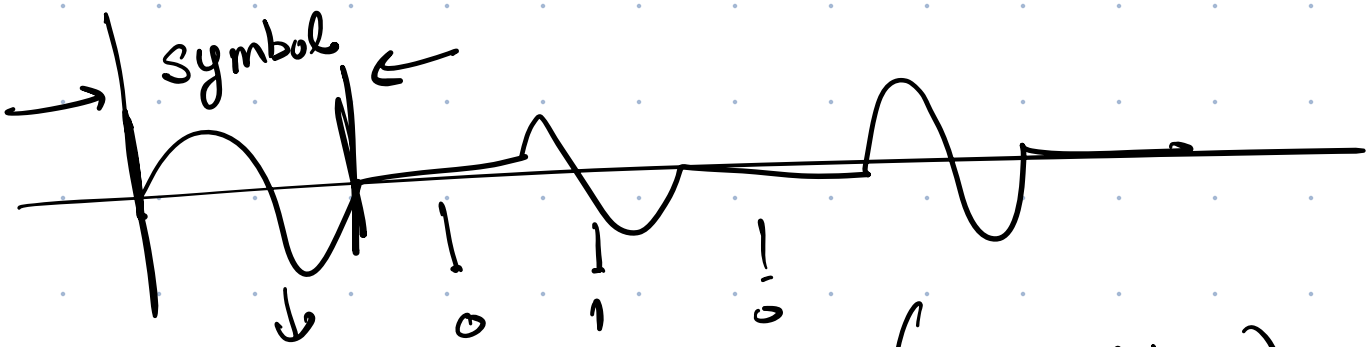
10110101

on-off keying

Sender

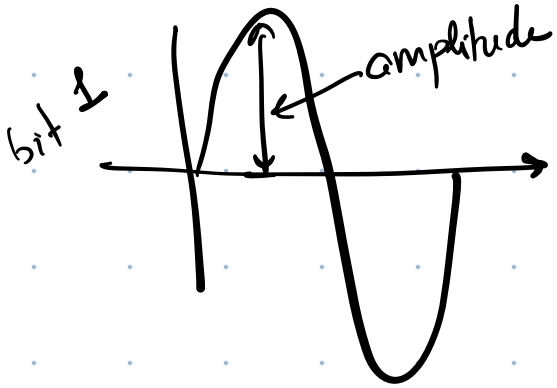


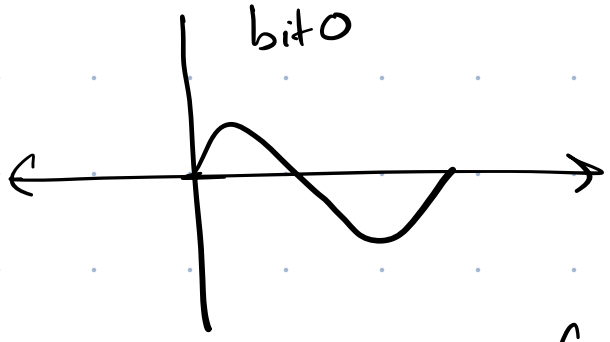
Receiver



bits → waves / symbol (modulation)

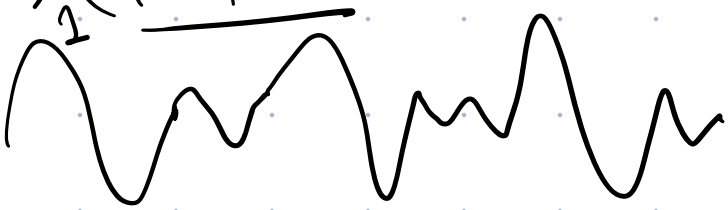
symbol → bit (demodulation)



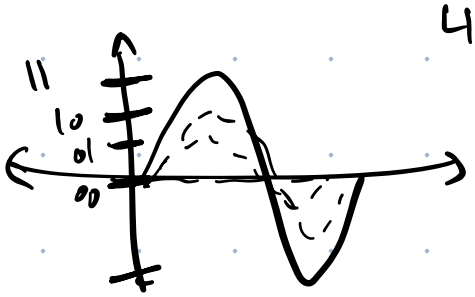


amplitude modulation (AM)

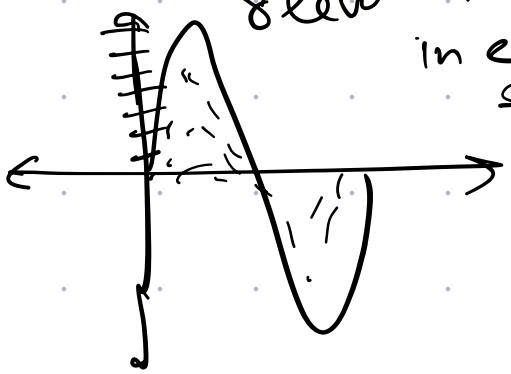
promise hello → (1011011) (data)



4-AM

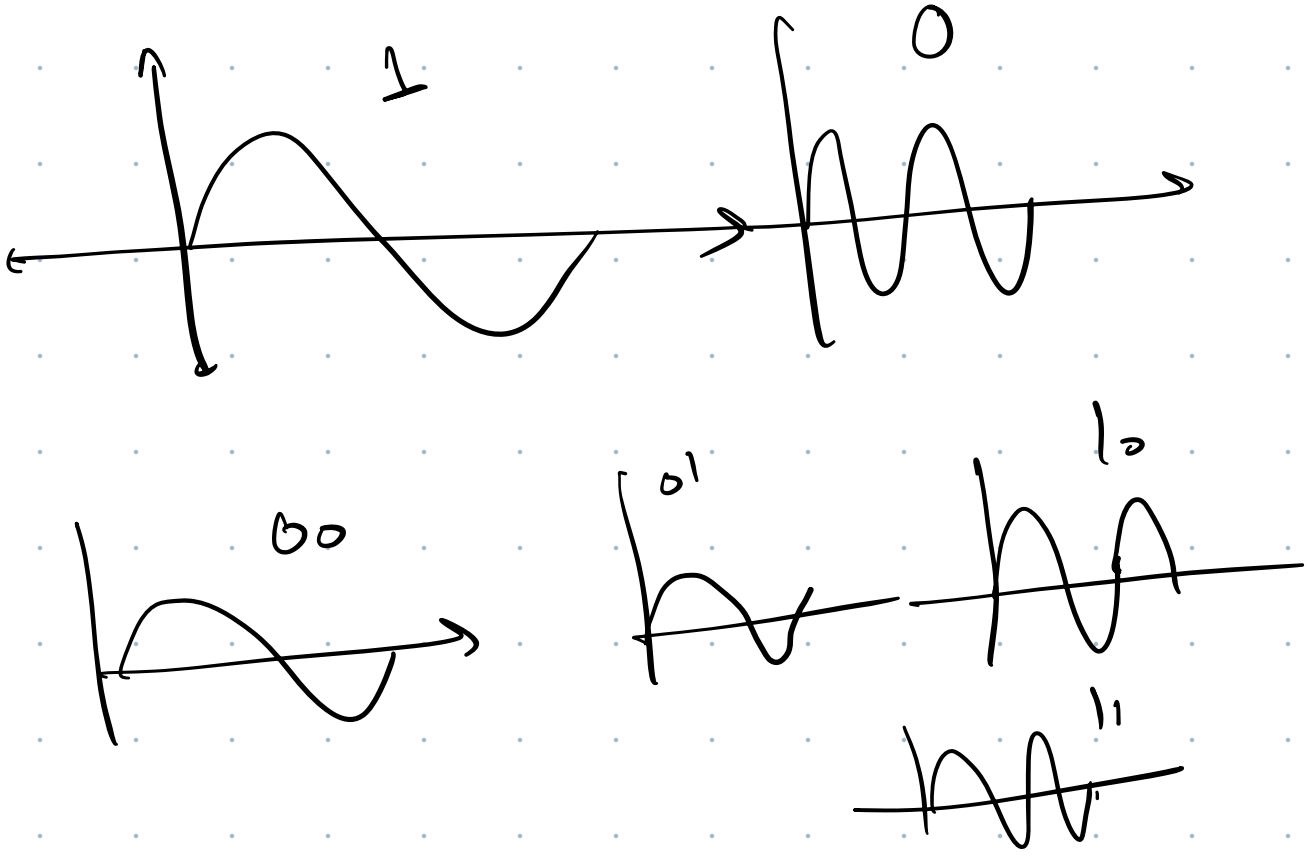


8 level → 3 bits in each symbol.

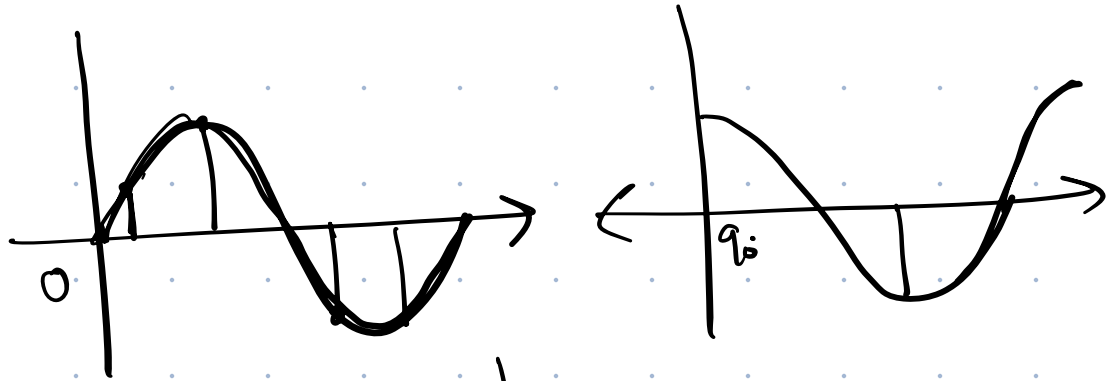


$$a \propto \left(\frac{d}{d}\right)^2$$

Frequency Modulation

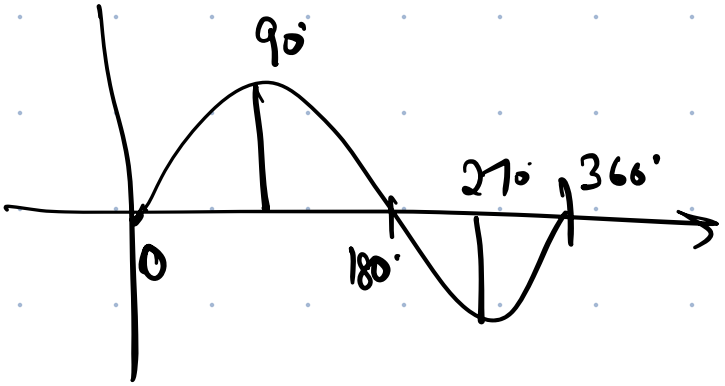


Phase

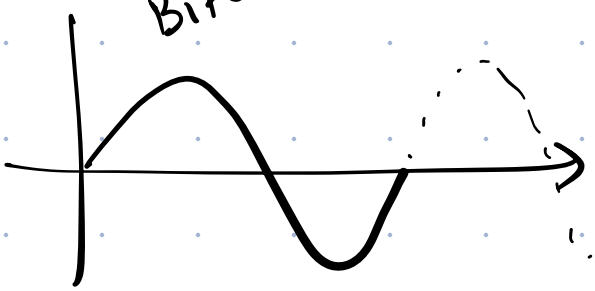


0 to 2π | 0 to 360 degrees

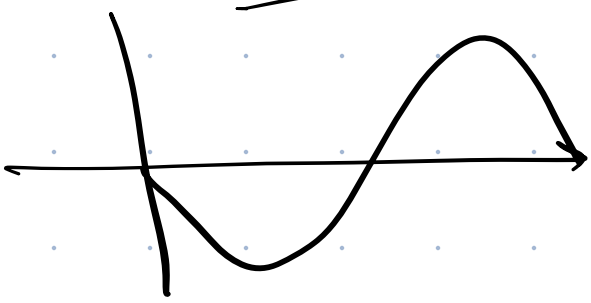
$$\phi = 2\pi f t \bmod 2\pi$$



Bit 0



Bit 1



5 GHz → 5×10^9/s

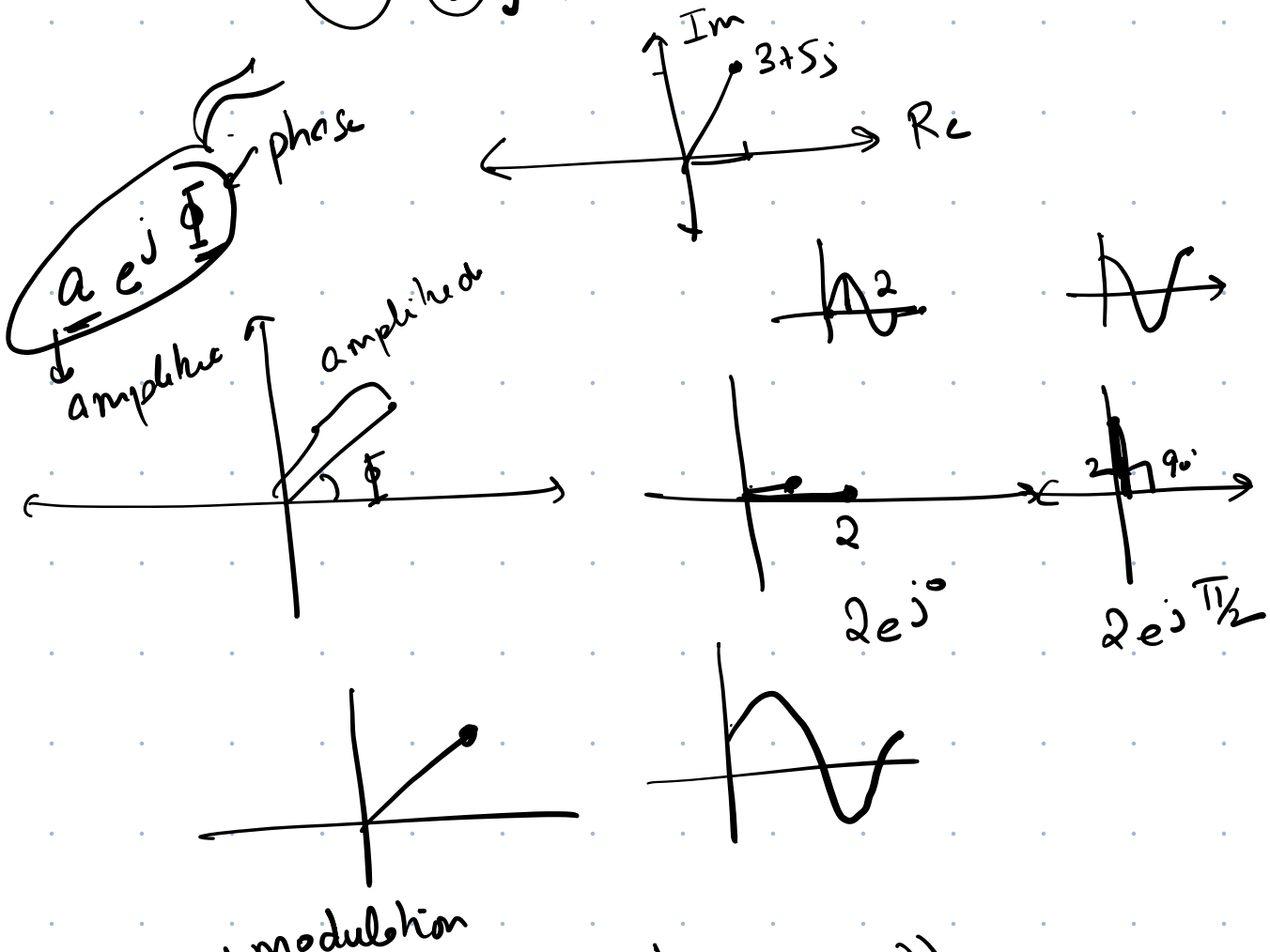
10^{-9} s

Binary Phase Shift Keying

COMPLEX NUMBER REPRESENTATION

$C = Re + j * Im$

$3 + 5j = \sqrt{-1}$ or $i = \sqrt{-1}$



modulation

bits → symbols → Radio)))

0,1,1,0

↓

waves

x_1, x_2, x_3, x_4

Sender.

demodulate

Radio → symbols → bits

(f) • y_1, y_2, y_3, y_4

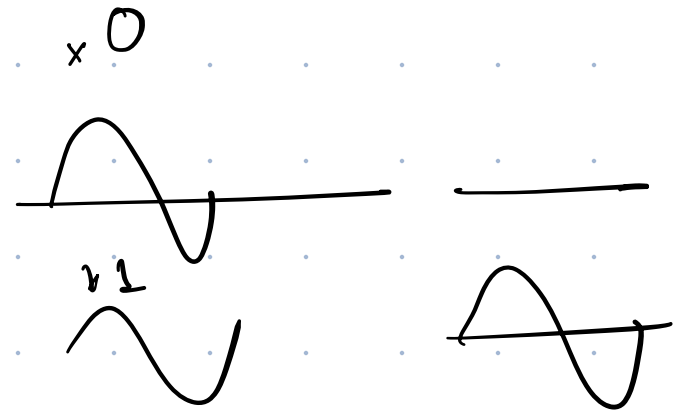
0, 1, 1, 1

Receiver:

OOK

0 → 0

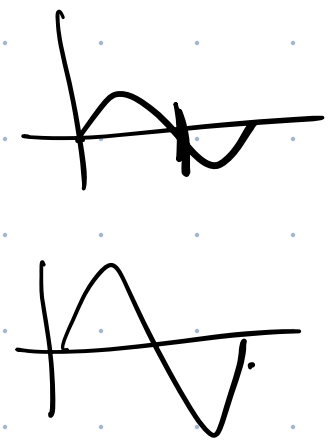
1 → 1



AM

0 → 0.5

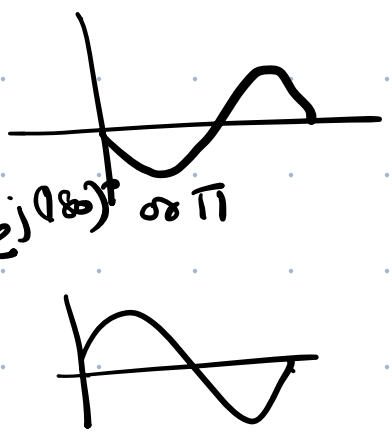
1 → 1



BPSK → phase shift keying

0 → −1 $= 1 e^{j(180)^\circ}$ or π

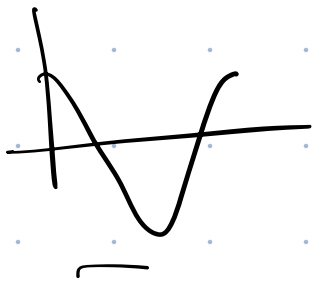
1 → 1



QPSK → quadrature

01 → e^{j0}

10 → $e^{j\pi/2}$



11 → $e^{j\pi}$

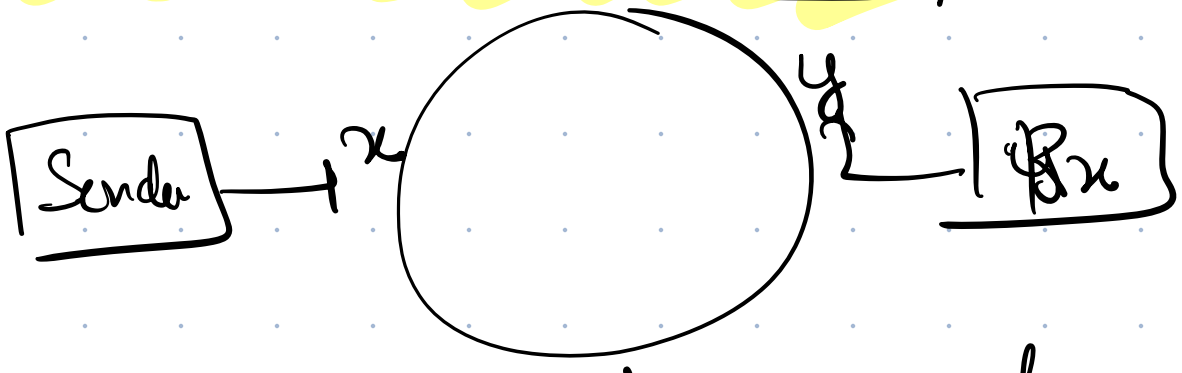
00 → $e^{j\frac{3\pi}{2}}$

01 → +1, 11 → -1 10 → $+1j$

00 → $-1j$

x y

WIRELESS CHANNEL



h ← wireless channel

$$y = hx + n$$ ← noise.

↳ decrease your amplitude.

↳ change your phase.

+1, -1, -1j, +1j

h = 0.5

Rx = 0.5, -0.5, -0.5j, 0.5j

h = 0.5j $\quad j^2 = -1$

$Rx = 0.5j, -0.5j, +0.5, -0.5$

Preamble

$1, 0, 1, 1, 0, 1, 1$

$\Downarrow$

$x_1, x_2, \ldots x_n$

$\underbrace{y_1, y_2, \ldots y_n}_{\text{preamble}}, y_{n+1}, y_{n+2}$

$y = hx + n$

$h' \neq \frac{y}{x}$

$x_{n+1} = \frac{y_{n+1}}{h'}$

$\frac{y-n}{x}$

SNR / SINR

Signal to noise ratio.

$y = hx + n$

$$SNR = \frac{|hx|^2}{|n|^2} = 1000$$

dB $dB(\alpha) = 10 \log_{10}(\alpha)$

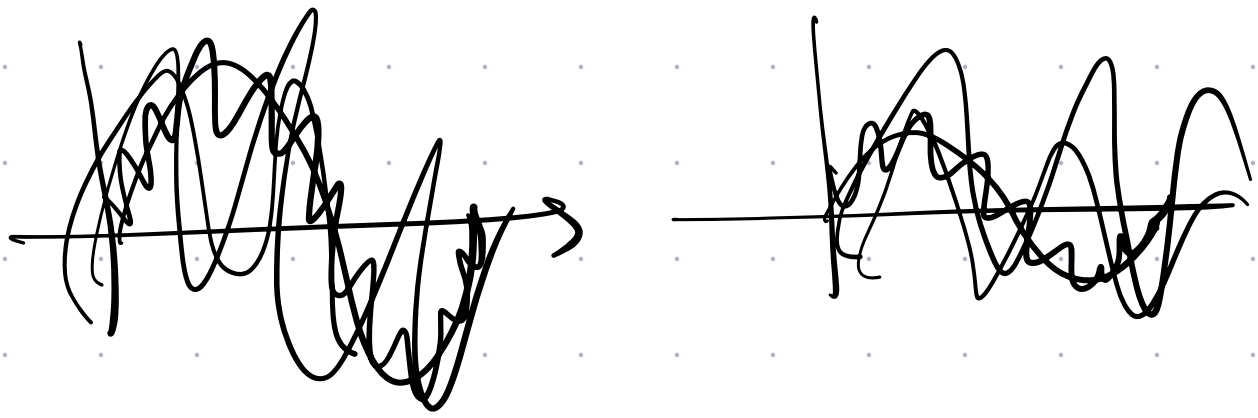
10dB → SNR 10

~~10~~ 20dB → SNR 100

1000

30 dB →

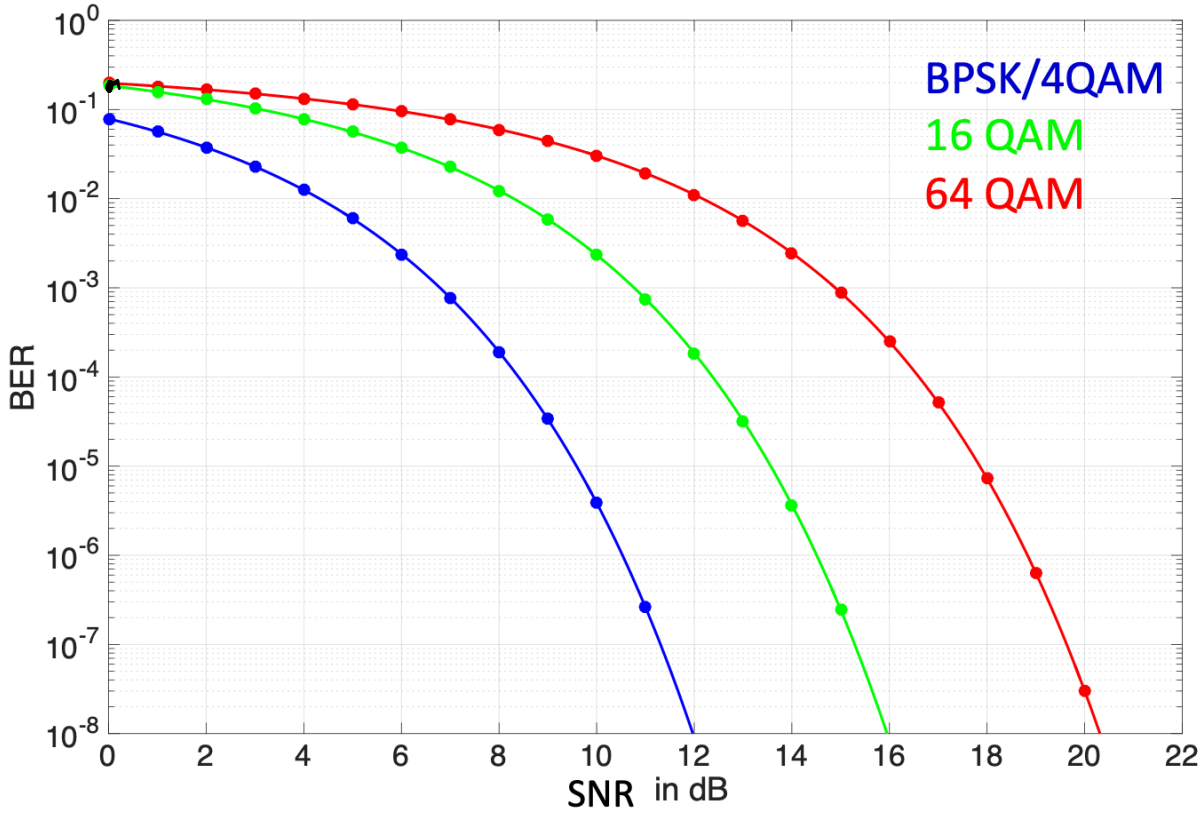
AM



SINR

Signal to interference & noise ratio.

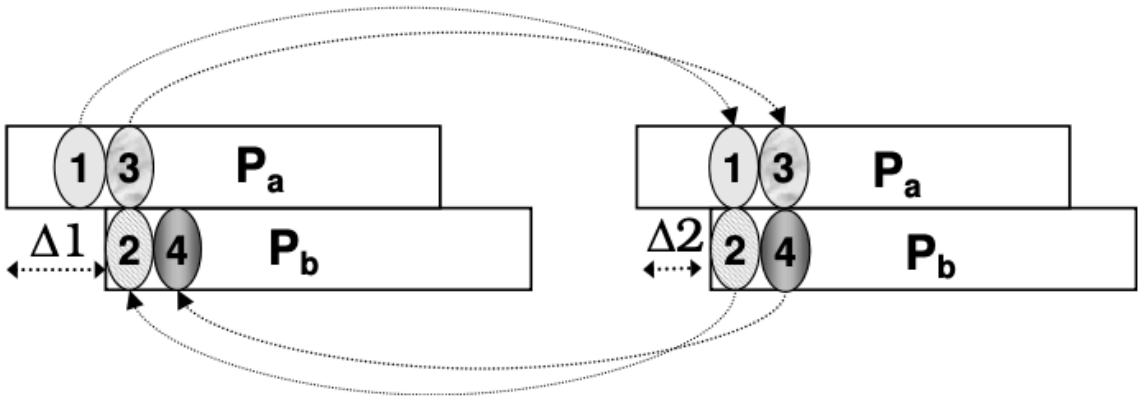
$$\frac{\text{Signal power}}{\text{Interference} + \text{Noise}}$$

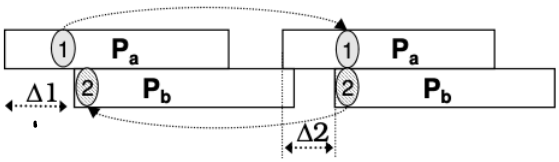

BPSK/4QAM
16 QAM
64 QAM
BER
SNR in dB
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0
2
4
6
8
10
12
14
16
18
20
22

DATARATE / CAPACITY

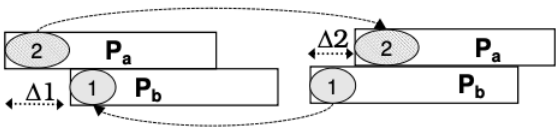
ZIGZAG

MOTIVATION

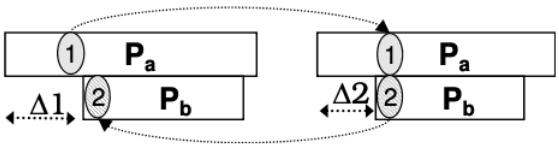

1
3
P_a
$\Delta 1$
2
4
P_b
1
3
P_a
$\Delta 2$
2
4
P_b



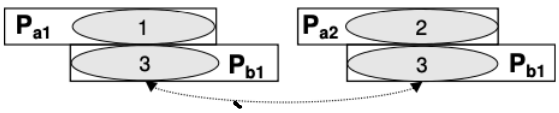
(a) Overlapped Collisions



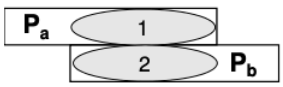
(b) Flipped Order



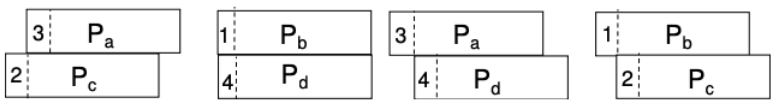
(c) Different Packet Sizes



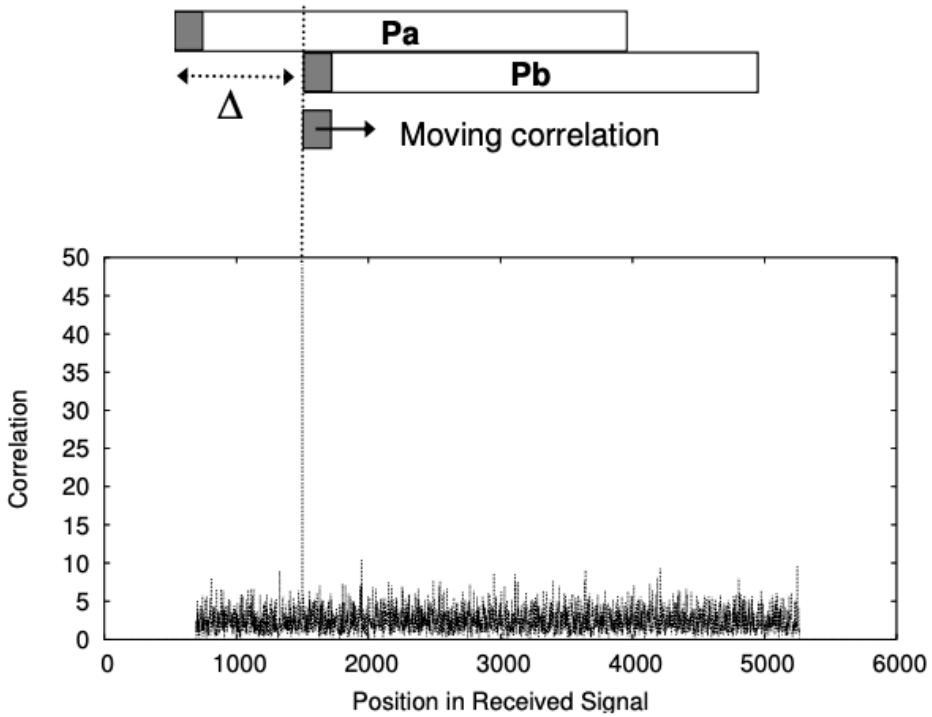
(d) Alice's Packets Enjoy the Capture Effect

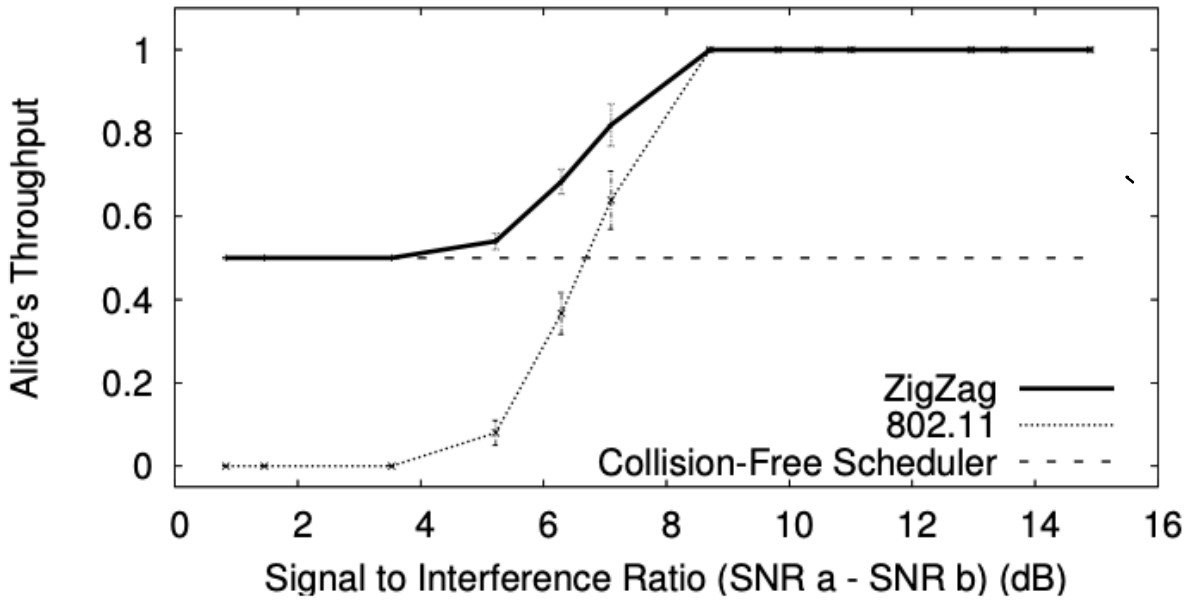


(e) Single Decodable Collision; Inefficient Choice of Bit Rates

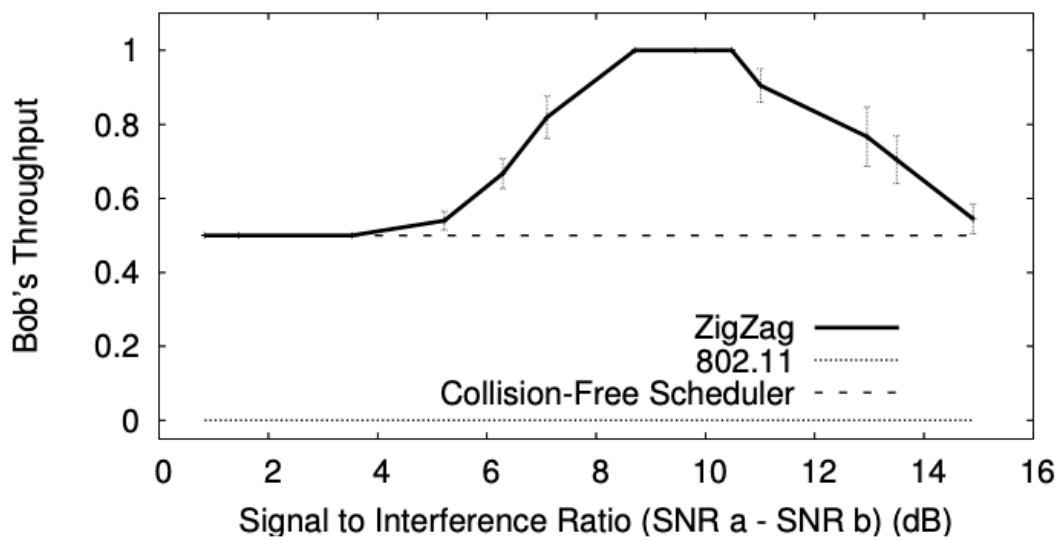


(f) Nodes A and B are hidden from C and D


Pa
Pb
Δ
Moving correlation
Correlation
50
45
40
35
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000
Position in Received Signal

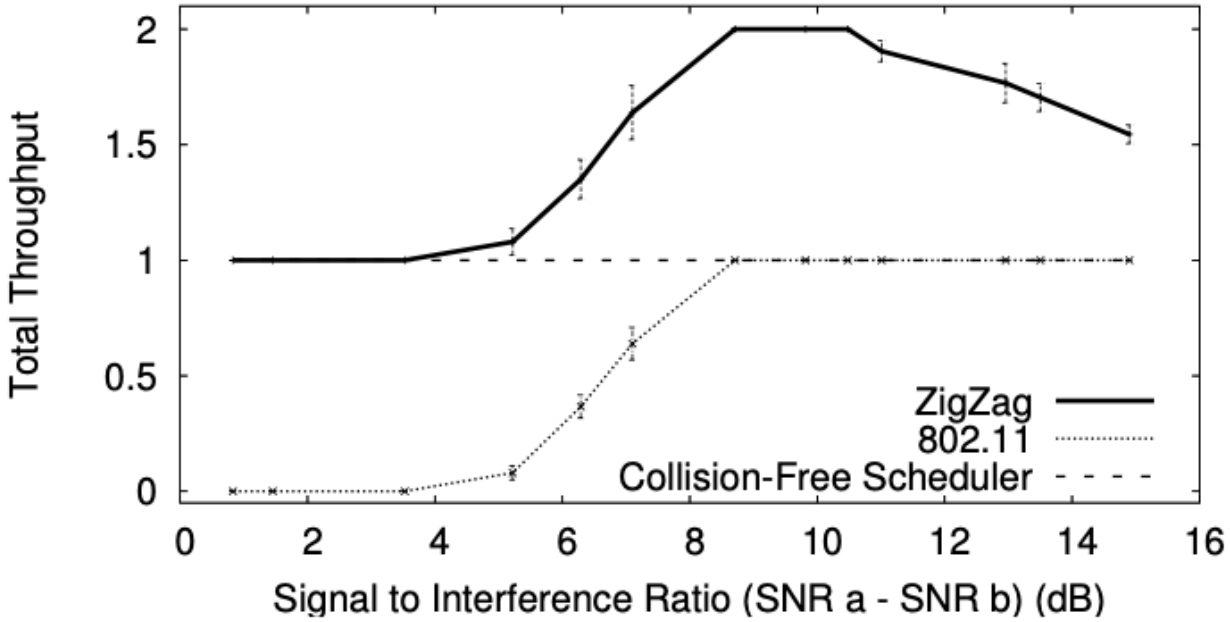


(a) Alice's Throughput



(b) Bob's Throughput

(b) Bob's Throughput



(c) Total Throughput